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<p>(54) Title: ANALOG VIDEO INTERFACE FOR A DIGITAL VIDEO DISPLAY</p>		
<p>(57) Abstract</p> <p>The invention relates to an analog video interface for a digital video display, comprising an analog video input (31) for receiving at least one analog video signal with composite or separate horizontal and vertical deflection signals; digitizing means (36) for digitizing said at least one analog video signal; means (41) for generating a basic clock signal having a frequency at least n times a desired video frequency, where $n > 1$; means (41, 43) for generating control signals for the digital display and a sampling clock signal for the digitizing means in synchronization with the basic clock signal. According to the invention, said display further comprises means (32) for determining the actual video frequency of the analog video signal on the basis of said received signals; said means for generating the basic clock signal comprising a programmable frequency synthesizer means responsive to said determining means for synthesizing the basic clock of a frequency at least n times said determined actual video frequency, where $n > 1$.</p>		

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Analog video interface for a digital video display

The invention relates to an analog video interface for a digital video display device, comprising
5 an analog video input for receiving at least one analog video signal with composite or separate horizontal and vertical deflection signals; digitizing means for digitizing said at least one analog video signal; means for generating a basic clock signal
10 having a frequency at least n times a desired video frequency, where $n \geq 1$; means for generating control signals for the digital display and a sampling clock signal for the digitizing means in synchronization with the basic clock signal.

15 Computer graphic display systems provided with e.g. a VGA display adapter usually employ a monochrome or colour cathode-ray tube display controlled by analog video signals (the analog voltage represents directly the brightness of the pixels of different colours). Most laptop computers employ digital liquid crystal display (LCD) panels. In certain 20 special models of desktop computers (PS), attempts have been made to replace the CRT display with a digital LCD, plasma or electroluminescence (EL) 25 panel.

Digital display panels require a parallel digital control, which means that the number of required control signal lines increases with the amount of colour information transferred to the screen.
30 Frame rate control (FRC) and dithering aim at achieving the same effect with a smaller number of control signals (i.e. without increasing the number of signal lines) by processing and pulsing the image information. These techniques usually cause flickering in 35 the image. The great number of lines is easy to place

by using a so-called flat cable within the laptop computer, whereas the display panel is positioned in a separate housing in larger desktop computers, and the image information is transferred to the display panel through a separate external video cable. When the number of signal lines increases, the video cable becomes stiffer and takes more space, which is a major disadvantage in view of the use of the display. In addition, different display panels require different interfaces for the signal lines or even different control and timing signals to operate. This would require the use of different cables for different display panels. In addition, the positioning of the image on the screen varies from one panel to another and may even require different timings for proper operation. Different panels support different numbers of colours, deviating from each other in this respect too (cf. the number of digital signal lines). Furthermore, the digital signals of the video cables easily interfere with the environment (RFI, EMI, EMC).

Digital signals in digital display panels require a non-standard display adapter with interfaces deviating from the conventional analog video interface. For the time being, display adapter circuits supporting the digital display panel are not produced on any larger scale, wherefore they are more expensive than mass-produced circuits supporting solely the analog cathode ray tube.

As appears from the above, a wider use of digital LCD, plasma or EL displays is greatly limited by the fact that the control signals, interfaces and display adapters supporting them deviate both from each other and especially from conventional display adapters (such as VGA) established as *de facto* stand-

ards and associated interfaces, which are used in most computer equipments. Accordingly, there is an apparent need to be able to control a digital display panel e.g. by a VGA display adapter via an analog 5 video interface complying with the present standards. This, in turn, involves that an interfacing equipment has to be provided in association with the digital display panel to digitize the analog video signal and generate control signals for each particular display 10 panel. This, however, involves some major problems.

EP 0 269 199 A discloses an LCD display, wherein a fixed basic clock frequency is generated locally. This basic clock frequency is a multiple of the desired video frequency. Then a control pulse is provided which is synchronized with the incoming horizontal synchronizing signal and the basic clock. A sampling clock is obtained by dividing the basic 15 clock by the control pulse.

However, to operate properly, a digital display 20 panel requires a clock signal appropriately and accurately phased with the analog video signal, as otherwise there may easily occur flickering in the image displayed on the screen. Similarly, the sampling frequency must always be as close as 25 possible to the video frequency of the used display adapter. Although the video frequencies of e.g. the VGA display adapters have values complying with the de facto standards, they are not always observed accurately in the adapters so that it is very difficult 30 to retain the required synchronization over the entire image area of the digital display panel. In addition, the video frequency of the display adapter does not remain constant but may roam, though within relatively narrow limits. Therefore the display 35 of EP 0 269 199 A does not ensure high image

quality since the video frequencies of the video source and the display may differ substantially from each other. One easy solution to the problem would be to supply the required clock signal directly from the 5 display adapter through a cable. This, however, results in incompatibility with a display adapter complying with the de facto standard as the cable connection of such a compatible display adapter does not contain a video clock signal. In addition, interference problems easily occur when a radio-frequency 10 clock signal of 25 to 30 MHz is transferred through the video cable.

The object of the present invention is to provide an analog video interface for a digital display 15 device, which is compatible with a desired widely-used analog display adapter and the cable connection thereof while enabling a flicker-free image of high quality on the digital display panel.

This is achieved by means of an analog video 20 interface for a digital video display of the type described in the introduction, which according to the invention is characterized in that said display further comprises means for determining the actual video frequency of the analog video signal on the 25 basis of said received signals; said means for generating the basic clock signal comprising a programmable frequency synthesizer means responsive to said determining means for synthesizing the basic clock of a frequency which is at least n times said 30 determined actual video frequency, where $n \geq 1$.

In the invention, a synthesized clock signal is utilized in place of the fixed clock signal and sampling clock of the digital display panel so that the frequency of the synthesized clock signal is 35 adjusted in accordance with the actual video fre-

quency of the video signal received. To determine the actual video frequency of the received video signal with sufficient accuracy, the video interface according to the invention calculates the video frequency 5 on the basis of the duration of the received horizontal or vertical deflection period and the video clock periods (pixels) in the deflection period for each specific display resolution. Preferably, a basic clock having a frequency which is a multiple of the 10 actual video frequency is synthesized on the basis of the calculated actual video frequency, and the sampling clock and all the control signals of the digital display are derived from the basic clock frequency. A quadruple basic clock frequency ($n = 4$) is 15 particularly advantageous as the Inventor has discovered that, to obtain a stable interference-free image (without flickering of pixels) on the screen, the sampling clock period must not deviate from the video clock period of the received analog video 20 signal by more than 1/4 of the video clock period. In addition, the sampling instant always has to coincide with the stable portion of the video signal, which prevents the quantizing error and provides a stable flicker-free image on the screen. If the sampling 25 time coincides with the time of change of the video signal, flickering or incorrect image information appears on the screen. By the present method the sampling clock and all display control signals can be synchronized with the received video signal with a 30 sufficient accuracy. The sampling clock and the video clock of the digital display are easy to obtain by dividing the basic clock frequency by n , e.g. by 4. Correspondingly, the horizontal and vertical deflection signals required by the display and other 35 possible control signals and pulses can each be form-

ed by software to contain a number of basic clock periods determined by register parameters. So the video interface according to the invention enables the timing of all signals to be adjusted by software in accordance with the requirements of the display adapter (video signal) and the digital display used. The generated horizontal deflection signal is easy to synchronize instantaneously with the received horizontal deflection signal by increasing or decreasing the number of basic clock periods contained in the horizontal deflection period (synchronizing pulse). By generating two short horizontal synchronizing pulses during each horizontal deflection period, interlaced scanning can be effected in a simple manner on the digital display. Correspondingly, when the display adapter is in the character mode, the image can be stretched in the vertical direction by generating more than one horizontal synchronizing pulses during some of the horizontal deflection periods, thus producing additional empty lines between the character lines. Furthermore, in the character mode of the display adapter, where there are usually 720 pixels per horizontal line, the video signal can be outputted with acceptable quality by a digital display panel having 640 pixels per horizontal line by omitting every ninth sampling clock pulse and the corresponding video clock pulse of the digital display, as a result of which every ninth pixel of the video signal will not be displayed on the screen.

In the video interface according to the invention, the brightness can be adjusted on the screen by varying the voltage level of the lower digitizing limit of the video signal while maintaining the size of the voltage range to be digitized

unchanged or by controlling the operation of the inverter of background light. To adjust the contrast, the upper digitizing limit is varied and the lower limit is kept constant. In addition, the brightness, 5 contrast, colour and/or word length corrections required by the properties of the digital video display to be controlled can be performed on the digitized video data nearly arbitrarily by means of a look-up type conversion memory provided after the digitizing 10 means.

By means of the video interface according to the invention, various digital monochrome and colour display panels (LCD, TFT LCD, EL) can be interfaced by means of an analog interface complying with the de facto standard and a flexible standard video cable to standard VGA adapters and other analog display adapters (such as 8514/A, XGA, multimedia adapters). The video interface according to the invention is thus independent of the display adapter (and nearly 15 independent of the resolution) and it offers compatibility not only with 640-pixel display modes but also with 720-pixel character modes. Due to its internal digital connection the interface can be specially designed for the display panel of each 20 manufacturer. In addition, due to the conversion memory, the contrast and the brightness can be adjusted by software even specifically for each user or application, and the colour scale of the display panel can be corrected (gamma correction) for different panels, or the user can define the colour 25 scale.

In the following the invention will be described in more detail by means of illustrating embodiments with reference to the attached drawings, 30 35 in which

Figure 1 is a block diagram illustrating a computer display system in which the video interface according to the invention is applicable;

5 Figure 2 shows the screen of a video display device, illustrating how the horizontal and vertical synchronizing signals of the video signal position the image on the screen;

10 Figure 3 is a block diagram illustrating an analog video interface according to the invention;

15 Figure 4 is a block diagram illustrating the control unit of Figure 3;

Figure 5 is a timing diagram illustrating the sampling of an analog video signal;

15 Figures 6, 7 and 8 are timing diagrams illustrating the synchronizing of the horizontal deflection signal;

Figure 9 is a timing diagram illustrating the removal of a pixel in the character mode;

20 Figures 10 and 11 are timing diagrams illustrating the generation of horizontal synchronizing pulses in an uninterlaced and interlaced display mode, respectively;

Figure 12 is a timing diagram illustrating the stretching of an image;

25 Figure 13 is a block diagram illustrating the use of an FRC circuit for controlling a colour panel; and

30 Figure 14 is a block diagram in which an intermediate memory is used for controlling a monochrome display divided into two blocks.

35 The invention can be applied in the control of any display device controllable by a digital video signal. Such a display device may be e.g. a liquid crystal display, a plasma display, an electroluminescence display, etc.

Figure 1 shows a computer system in which the invention can be applied. The computer system comprises a personal computer 1 (PC) to which a keyboard 3, a mouse 4 and a display device 2 can be connected. 5 The PC 1 contains a display adapter which generates a video signal which may consist of several different physical signals and which is applied to the display device 2 through a video cable 5.

Figure 2 illustrates deflection or control 10 signals for the video signal and their influence on the positioning of the image on the screen of the cathode ray tube. A horizontal line or horizontal deflection period HPER means a period during which one horizontal line is scanned from the left to the 15 right across the screen and back to the start of the next horizontal line. The HPER comprises an active display period H_{ACTIVE} , which defines an active image area 21 on the screen, and a blanking period HBLANK, which comprises at least a front porch HFP, a horizontal synchronizing pulse HSYNC and a back porch HBP. The retrace of the electron beam to the start of 20 the next line takes place during the blanking period HBLANK. Correspondingly, an image or vertical deflection period VPER comprises a display period V_{ACTIVE} and a blanking period VBLANK which contains at least a front porch VFP, a vertical synchronizing pulse VSYNC and a back porch VBP. All the above-mentioned control 25 periods of vertical deflection are formed of the multiples of the horizontal deflection period HPER, the number of the multiples being determined in each particular case by programmable control parameters, 30 as will be described below.

The durations of the display periods H_{ACTIVE} and V_{ACTIVE} in relation to the periods HPER and VPER usually 35 determine the width and height of the displayed

image, i.e. the image size. The positions of the synchronizing pulses HSYNC and VSYNC in relation to the respective display periods H_{ACTIVE} and V_{ACTIVE} determine the position of the image in the horizontal and 5 vertical direction.

The video frequency means the frequency of the video dot clock, i.e. the video clock, whereby one video clock period is the time required to display 10 one pixel on the screen. The resolution is the number of the video periods in the period H_{ACTIVE} in the horizontal direction, and the number of the periods HPER 15 of the period V_{ACTIVE} in the vertical direction.

In most modern personal computers (such as IBM PC compatible) a VGA (Video Graphics Array) display 20 adapter has replaced the former EGA, CGA, MDA and HGC display adapters. Although the video interface according to the invention can, in practice, be applied to any display adapter, the VGA adapters and the more recent adapters (such as XGA, 8514/A) are 25 more interesting in view of the compatibility to be obtained by the invention, wherefore the invention will be described below by using these as examples.

Figure 3 shows an interfacing equipment according 30 to the invention for connecting a digital LCD display panel to an analog video signal. The principle of the equipment is to digitize the received analog video signals in real time and generate appropriate timing signals for the display panel, so that the digitized video signals can be transferred in serial form to the electronics of the display panel. By means of the video interface according 35 to the invention, all display modes of a VGA display adapter of the de facto standard can be effected by a digital LCD panel similarly as on the screen of an analog CRT display shown in Figure 2. The compatible

VGA display adapter is typically able to produce a character mode of a 720x400 resolution and a graphics mode of a 640x480 resolution (the most widely used VGA display modes).

5 The equipment of Figure 3 is divided into several blocks on functional grounds. These blocks are an analog video input 31, a CPU microadapter 32, a communication channel interface circuit 33, an EEPROM memory 34, a control circuit 35, A/D conversion circuits 36, a conversion memory 37, an output buffer 38 and an LC display panel 39.

10 The video input 31 is mainly intended to be connected to a VGA display adapter of the *de facto* standard, the video interface of the VGA adapter 15 employing the signals of Table 1 for the video transfer.

TABLE 1
Signal interface of a VGA display adapter

SIGNAL	NAME	DESCRIPTION
1	R	Analog control signal for red colour. Used only with a colour display device.
2	G	Analog control signal for green colour or for monochrome level. Monochrome-level control is used only with a monochrome display.
3	B	Analog control signal for blue colour. Used only with a colour display device.
4	ID2	Identification signal 2 for a display device.
5	Reserved (gnd)	Reserved (grounding)
6	R-Return	Grounding of red analog signal (pin 1). Used only with a colour display device.
7	G-Return	Grounding of green colour or monochrome level signal.
8	B-Return	Grounding signal of blue colour. Used only with a colour display device.
9	Key	Coding (the pin hole of the connector blocked).
10	GND	Grounding of digital signals.
11	ID0	Display device identif. signal 0
12	ID1	Display device identif. signal 1
13	HSYNC	Horizontal deflection signal for the display device
14	VSYNC	Vertical deflection signal for the display device
15	Reserved	Reserved

5 In the preferred embodiment of the equipment according to the invention, only the R, G and B video signals (0 to 0.7 V) and the TTL-level horizontal and vertical deflection signals HSYNC and VSYNC of the signals of Table 1 are utilized. The analog video signals R, G and B are applied to separate A/D converters 36. The received horizontal deflection signals HSYNC and VSYNC are applied to the control circuit 35 and the CPU 32.

10 The CPU controls and initiates the operations of the entire equipment and selects the right display mode. In addition, the CPU 32 may communicate with the central unit 1 of the PC (Figure 1) according to the principles disclosed in FI Patent Application 15 914435 through a standard VGA video interface and the cable 5 shown in Figure 1 by using the communication link 33. The PC is thereby able to control the display device by software through the video interface. The control program may contain the control of image 20 position, brightness, contrast, stretching and colour correction, the selection of the display mode, etc. Correspondingly, the CPU 32 may transfer various display device identification and status data to the PC 1.

25 When controlling the equipment the CPU 32 utilizes the device characteristics stored in the memory 34. The memory 34 is non-volatile, and it may be re-programmable by the PC software through the communication link 33. The memory may contain parameters 30 representing several different display modes, which parameters are utilized by the CPU 32 when the respective display mode is used. Typically, image positioning, display mode, contrast, brightness and colour correction parameters are stored in the memory

34.

The CPU 32 identifies the display mode used by the display adapter on the basis of the deflection signals it receives (their timings and polarities) and initiates the equipment according to the display mode. As mentioned above, the sampling frequency should be very close to the video frequency used by the display adapter to obtain a stable interference-free image by the A/D converter 36. As the video frequencies of the different display adapters may, however, deviate significantly from the nominal VGA video frequency, the interfacing equipment according to the invention has to be able to determine the video frequency of each video signal received by it with sufficient accuracy.

In the preferred embodiment of the invention, the CPU 32 calculates the video frequency by means of the horizontal deflection signal HSYNC received by it. It thereby utilizes the information that the horizontal resolution of the VGA display adapter (the active video period H_{ACTIVE} in Figure 2) comprises 640 pixels, that is, the length of the horizontal deflection period HPER corresponding to the video clock period is 800 pixels or video clock periods. The CPU calculates the time required for several horizontal deflection periods HPER of the received horizontal deflection signal HSYNC by means of an accurate internal reference clock signal of the equipment. The actual duration of the video clock period is obtained by dividing the calculated duration of the horizontal deflection period HPER by the predetermined number 800 of the video clock periods. The result indicates to what extent the video frequency used by the VGA display adapter deviates from the nominal video frequency of the above-mentioned VGA resolution. On the

basis of this information the CPU 32 produces an appropriate register value for the control circuit 35 to be programmed and applies it to the control circuit 35. For instance, when the calculated length of 5 the horizontal deflection period HPER is 31.778 microseconds (the deflection frequency being 31.468 kHz), the length of one video clock period is $HPER/800=39.721$ ns, which corresponds to the video frequency 25.175 MHz. If the horizontal deflection 10 period HPER contains more or less than 800 pixels, the PC may transfer a new value to the CPU 32 through the communication link 33.

The control circuit 35 generates control signals synchronized with each other: a sampling 15 clock SAMPLE of the A/D converter 36, a control clock LOAD of the output buffer 38, and a video clock CLOCK of the digital display 39, and deflection and control signals HSYNC', BLANK', VSYNC'. The control circuit 35 contains a phase-locked loop (PLL) and a voltage-controlled oscillator (VCO) 41. In the preferred 20 embodiment of the invention, the PLL operates at a clock frequency 4xCLK four times the video frequency (n=4), and this clock frequency is synthesized by the VCO of the circuit 41 on the basis of the parameters supplied by the CPU 32. The frequency synthesis range 25 is relatively narrow, being 24 to 29 MHz, so that a sufficiently stable clock frequency is obtained. To decrease the RFI interferences, the circuit 41 is preferably an integrated circuit, such as ICS1394, and the clock signal 4xCLK is used only within the 30 circuit 41. The circuit 41 thereby also contains the registers required to generate the clock signal 4xCLK and the control signals CLOCK, SAMPLE and LOAD. The circuit 41 also contains a crystal XTAL which is used 35 as a reference frequency in the synthesizing of the

signal 4xCLK and as an accurate reference clock for the CPU 32. Before being applied to the circuit 41, the polarities of the received horizontal and vertical deflection signals HSYNC and VSYNC are set by a 5 polarity adjusting circuit 44B in accordance with the internal polarities of the circuit 35 and synchronized by a digital synchronizing stage 45 with the internal clock signal of the circuit 35.

The circuit 35 also contains a deflection controller 43 which produces appropriate deflection signals HSYNC', VSYNC' and BLANK' for the display panel 39, the signals being synchronized with the received deflection signals HSYNC and VSYNC and consisting of the same elements HSYNC, HBP, H_{ACTIVE} , HFP, 10 VSYNC, VBP, V_{ACTIVE} and VFP as the CRT video signal illustrated in Figure 2. The controller 43 contains the control registers to be used in the deflection. Due to the programmable deflection controller 43 it is easy to use different components (A/D, conversion 15 circuit, FRC circuit) in the equipment and adapt the timings of the equipment to the used components. In the preferred embodiment of the invention the horizontal deflection signals HSYNC' and BLANK' are formed by a programmable number of the periods of the 20 4xCLK clock signal, and the horizontal synchronizing signal VSYNC' consists of a programmable number of horizontal deflection periods HPER. The polarities of the generated deflection signals are adapted by the 25 polarity adjusting circuit 44A to each display panel 39.

The circuits 41, 43, 44A and 44B are controlled by parameters programmed in control registers 42 by the CPU 32 over a control bus 30.

As mentioned above, the circuit 41 operates at 35 a frequency four times the video frequency, and so it

is usually possible to synchronize all the signals generated by the circuit 35 with the horizontal deflection signal HSYNC at an accuracy at least one fourth of the video clock period. The clock periods 5 of the sampling clock SAMPLE and the digital display 30 each consist of four periods of the basic clock 4xCLK (the original actual video frequency).

Sampling of the analog signals R, G and B by the A/D converter is illustrated in Figure 5. The A/D 10 conversion is effected at a time determined by the circuit 35 by using the sampling clock signal SAMPLE so that the sampling will always take place at a stable portion of the video signal, which prevents the quantizing error and provides a stable flicker-free 15 image on the screen. As shown in Figure 5, this is effected by timing the rising front edge of the sampling pulse comprising two periods of the basic clock 4xCLK at the start of each video clock period, so that the falling back edge of the pulse, which activates the sampling, will fall in the middle of 20 the video clock period at a stable signal point.

As the interfacing equipment shown in Figure 3 is started at an arbitrary moment with respect to the 25 status of the VGA display adapter (the deflection period of the received video signal), the control circuit 35 has to be able to automatically phase-lock the horizontal synchronizing pulse HSYNC generated by it to the received horizontal synchronizing pulse HSYNC when changing the display mode or when starting 30 the equipment, for instance. Another reason why this property is necessary is that the internal clock CLOCK of the equipment is not accurately equal to the video frequency of the received signal.

Referring to Figure 4, to effect the above-35 mentioned operation, the phase-locked loop of the

circuit 41 compares the horizontal deflection pulse HSYNC received from 45 and synchronized with 4xCLK with the generated horizontal deflection pulse HSYNC' at the clock frequency 4xCLK. If the pulses HSYNC and 5 HSYNC' are exactly at the same phase, no adjustments will be carried out. If the front edge of the pulse HSYNC' (change of state) occurs later than the front edge of the received pulse HSYNC, the phase of the deflection signals HSYNC', VSYNC' and BLANK' to be 10 sent to the digital display 39 and that of the sampling signal SAMPLE and the signal LOAD is advanced by "stealing" one or more of the clock pulses 4xCLK controlling the signals. In the case of Figure 6, the front edge of the pulse HSYNC' is two 15 4xCLK periods behind, wherefore the above-mentioned phase shift is effected by shortening this pulse HSYNC' by two clock periods 4xCLK.

Correspondingly, when the pulse HSYNC' comes 20 too early with respect to the pulse HSYNC, the phase of the above-mentioned control signals is delayed by adding to them one or more 4xCLK clock periods, as shown in Figure 7.

An alternative solution to effect synchronization is that, instead of changing the number of 25 the basic clock pulses, the phase-locked loop controls the VCO and thus the basic clock frequency. If the generated pulse HSYNC' is ahead of the synchronized pulse HSYNC, the duration of the period HPER is increased by decreasing the basic clock frequency. If the generated pulse HSYNC' is behind in 30 time, the basic clock frequency is increased so that the duration of the period HPER is shortened.

The pulses HSYNC and HSYNC' are always compared 35 at the front edge of the pulse HSYNC. The back edge of the deflection pulse HSYNC' is used to determine

the position of the image on the display panel 39. The addition/removal of the clock pulses 4xCLK is performed after the comparison very rapidly during the same deflection pulse, and so the correction 5 immediately applies to the ensuing deflection period HPER. In this way all the control signals generated by the control circuit 35 remain synchronized with the status of the received video signal and the image is displayed on the screen at the right position 10 without interference.

A simpler alternative way to effect synchronization is to use a synchronized HSYNC pulse in a controlled manner for setting a HSYNC' counter register contained in the deflection control circuit 15 43 and allowing the counter to operate after the termination of the pulse HSYNC, as shown in Figure 8. In this way, the output of the counter produces a pulse HSYNC' equal in length to the controlling pulse HSYNC, while the phase difference between the pulses 20 is no more than one period of the clock signal 4xCLK.

As mentioned above, the CPU 32 is able to identify different character modes and an interlaced display mode by means of the deflection signals HSYNC 25 and VSYNC. In the interlaced display mode (used in the television, for instance), the even and odd lines of the image are produced separately during successive image fields. On detecting this mode, the CPU 32 programs the circuit 35 to produce, in place of one 30 pulse of normal length, two pulses HSYNC' shorter than normally immediately in succession during each horizontal deflection period to cause the display panel 39 to shift its internal pointer onwards over one horizontal line. In this way the display device 35 is made to operate in the interlaced display mode.

Figures 10 and 11 show the generation of the pulses HSYNC' in an uninterlaced and interlaced display mode, respectively.

The VGA character modes usually comprise 720 pixels per horizontal line. In order that an adequate image quality could be achieved with a digital display panel able to display 640 pixels per horizontal line, every ninth pixel has to be omitted. The easiest way to accomplish this is to change the type 5 font by the PC and start to use the resolution of 640 pixels on the VGA display adapter. Certain operating systems, such as OS/2, and application programs, however, require compatibility with the CRT displays 10 (invariable VGA environment). In the interfacing equipment according to the invention, it is possible 15 to achieve compatibility with these programs by leaving every ninth pixel of the received video signal undigitized. Practically this pixel does not contain any information, as it is used to separate the different characters from each other on the screen. 20

On detecting a normal VGA character mode, the CPU 32 programs the circuit 35 to omit the sampling pulse at every ninth pixel and at the same time to remove the corresponding pulse of the video clock 25 CLOCK of the display panel 39, beginning from the first pixel after the start of the period H_{ACTIVE} of the signal HBLANK', as shown in Figure 9. In lower-resolution display modes (e.g. 40x25 character mode), the corresponding pulses are omitted both at the 17th 30 and 18th pixel, so that the corresponding display resolution of the display 39 is 360x400 in place of the original 720x400, and the size of the character in the horizontal direction is 16 pixels.

In the character mode the image displayed on 35 the display 39 can be stretched by software in the

vertical direction by generating one or more additional HSYNC' pulses e.g. on every ninth horizontal line, as shown in Figure 12, similarly as in connection with the interlaced display mode. A 5 typical VGA character area comprises 9x16 pixels, and thereby at least one additional pulse is generated e.g. on every 16th line. In this way, empty lines can be produced between the character lines in the character modes. The number m of the additional horizontal 10 synchronizing pulses and the lines k on which they are generated can be selected in accordance with the character mode used and the desired stretching effect. For this purpose the deflection control circuit 43 comprises a line counter which generates 15 additional HSYNC' pulses on reaching a value stored in a control register of the controller 43, the number of the additional pulses being determined by a parameter stored in another control register of the controller 43.

20 The A/D converter 36 used in the equipment can be any converter intended or suitable for digitizing video signals. Suitable circuits include Bt 252 or Bt 254, manufactured by Brooktree Corporation, San Diego, USA. The former circuit comprises one A/D converter and the latter three parallel A/D converters. 25 After the A/D converter there is connected a conversion memory addressable by a digitized video output for shaping the digitized output data. The conversion memory 37 may be contained in the 30 integrated A/D converter circuit (Bt 252) or it may be a separate memory circuit. The conversion memory 37 contains a look-up table in which a respective output value is stored for each digitized video signal value, which output value is applied as a 35 digital video signal to the display 39.

By means of the conversion memory 37, the brightness or the contrast can be changed on the screen by changing the content of the conversion memory 37. The A/D converter circuit Bt 254 contains 5 six programmable D/A converters, by means of which the lower and upper digitizing limits (reference values for quantization) can be set for each video signal R, G, B. The above-mentioned change in 10 brightness can also be effected by changing the voltage level of the lower digitizing limit while keeping the size of the voltage range to be digitized unchanged or by controlling the inverter (through the D/A converter 40). The change of contrast can be effected by keeping the lower limit constant and 15 changing the range. The contrast of the display panel 39 itself is usually fixed to a certain value, which is difficult to change.

By means of the conversion memory 37, it is possible to effect, in addition to the brightness and 20 contrast adjustment, the changes required by the interfacing of different panel types (different word widths) and the colour correction by software. The colour filters of a TFT-type LCD panel usually provide a slightly purple image with the same control 25 parameters by which a CRT display produces a display quality very close to the original image. Such colour errors can be corrected (gamma correction) by the conversion memory 37, in addition to which it is possible to provide a positive image, effect images, 30 etc.

The conversion memory 37 can be replaced with a 35 RAMDAC circuit designed for the control of LCD panels and usually used in VGA display adapters. One such circuit is GD 6340 manufactured by Cirrus-Logic, by means of which the number of colours displayable on

the display 39 can be increased by using the FRC or dithering techniques. In certain cases, these techniques may be even more advantageous than a conventional conversion memory due to their higher 5 integration level (less external components). One such alternative connection is shown in Figure 13. The use of the above-mentioned GD 6340 circuit also enables the chaining of display devices, as the circuit supports both a digital display device control 10 and a cathode ray tube control.

Digital monochrome display panels (such as Sharp LM64148Z) are usually divided into two blocks (1/240 duty ratio), which have to be addressed simultaneously. Figure 14 shows a connection suitable for 15 the control of this kind of display panel, in which an additional controller 120 and an intermediate memory 121 are connected between the conversion memory 37 and the display panel 39. The controller 120 stores the digital video data provided by the 20 conversion memory 27 in the intermediate memory 121 and reads the data from the intermediate memory 121 in a manner required by the timing and addressing mechanism of the monochrome display and supplies the data to the display panel 39.

It is further possible to incorporate in the 25 interfacing equipment according to the invention functions by means of which the user is able to perform, through the communication link 33, various image adjustments by the keyboard or the mouse of the 30 PC by software e.g. as disclosed in Finnish Patent Application 914435 or through an external device interface 32A, to which e.g. a keyboard, control panel, mouse, inverter, control potentiometers for manual adjustments, etc., can be connected for 35 control or data transmission.

The alignment of the image on the screen can be effected e.g. in the following way. A bit map is stored in the memory of the display adapter of the PC, which map forms a rectangle which follows the 5 contours of the active image on the screen. By using the keyboard, the mouse or some other external device, such as a control panel, the image can be displaced on the screen by giving a command by the PC software to the CPU 32 to displace the image by one 10 4xCLK clock period to the right or to the left (similarly, by one line up or down in the vertical direction). The CPU 32 displaces the image by reprogramming the control registers of the deflection controller 43 of the control circuit 35 so that they 15 correspond to the new image position. The use of this control program requires a more thorough knowledge of the device from the user; on the other hand, the image can be positioned with a still greater accuracy and reliability.

20 The frequency deviation of the frequency synthesizer VCO of the control circuit 35 can also be made more accurate by storing a bit map in the memory of the display adapter of the PC, which map forms a dot lattice on the display 39 close to the right edge 25 of the image. When the frequency of the voltage-controlled frequency generator is changed, the dots in the lattice start to flicker when the sampling frequency deviates excessively from the video frequency used by the PC display adapter. By alternating 30 the sampling frequency between a lower and a higher value by the software of the CPU 32, the optimum frequency at which there occurs no flickering in the displayed image can be searched out. This way of adjustment is very suitable in cases where the timings 35 do not comply with the *de facto* standards.

After the image has been aligned in a desired manner, the CPU 32 can, if desired, be instructed to store the data concerning the timing in the memory 34. In an error situation the image can be restored 5 to the initial position or to the default value position by quick selection (e.g. by pressing a key in the PC).

With certain display adapter circuits, the image may be displayed in different positions in different modes even in the same timing mode. This does 10 not cause problems with a CRT display as the difference on the screen is insignificant. With the digital display panel 39, however, it causes the image to be displaced to the left or to the right so that a pixel group corresponding to the delay in the edge area of the image will not be displayed on the screen. The delay is due to the different internal switching paths of the display adapter in different display 15 modes. For instance, the most widely used VGA character mode 3+ uses a 720x400 resolution but the same timing mode as the graphics mode 6 (640x200). The operation of the display adapter circuit varies greatly from one mode to another, and the images may be positioned on the screen in different ways, as 20 described above.

In the equipment according to the invention, the problem can be solved e.g. by incorporating a communication request in the device software of the PC controlling the change of the display mode. The 25 communication request gives the interfacing equipment according to the invention accurate information about the used display mode. The CPU 32 searches the memory 34 for the image positioning parameters corresponding to this display mode and programs the image adjusting registers of the control circuit 35 so that they cor-

respond to these parameters. The device software of the PC may be stored in the EPROM memory of the PC or in the system memory as a terminate and stay resident program (TSR).

5 It is also easy to incorporate user or application specific adjusting values in the software of the CPU 32, which values are taken into use when the user changes or an application is started.

10 The interface according to the invention can be applied in the testing of analog display adapters by replacing the digital display with a computer. During one image field the video signal of the adapter is digitized by the interface according to the invention and a sum term is calculated from the digitized image 15 information, which sum term deviates from the sum term calculated for the test image if there is a failure in the display adapter.

20 The figures and the description related to them are only intended to illustrate the present invention. In its details, the analog video interface according to the invention may vary within the scope of the attached claims.

Claims:

1. Analog video interface for a digital video display, comprising
 - 5 an analog video input (31) for receiving at least one analog video signal with composite or separate horizontal and vertical deflection signals; digitizing means (36) for digitizing said at least one analog video signal;
 - 10 means (41) for generating a basic clock signal having a frequency which is at least n times a desired video frequency, where $n \geq 1$;
 - 15 means (41, 43) for generating control signals for the digital display and a sampling clock signal for the digitizing means in synchronization with the basic clock signal;
 - characterized in that said display further comprises
 - 20 means (32) for determining the actual video frequency of the analog video signal on the basis of said received signals;
 - 25 said means for generating the basic clock signal comprising a programmable frequency generator means responsive to said determining means for generating the basic clock of a frequency which is at least n times said determined actual video frequency, where $n \geq 1$.
2. Video interface according to claim 1, characterized in that the means (41) for generating the basic clock signal comprise a programmable frequency synthesizer means, and that the means (32) for determining the video frequency comprise a calculating means for calculating the length of the deflection period of the received horizontal and/or vertical deflection signal and dividing

it by a predetermined number of video frequency periods, and for programming the frequency synthesizer means to generate a corresponding n times greater basic clock frequency.

5 3. Video interface according to claim 2, characterized in that said predetermined number of video frequency periods is programmable so that it corresponds to each received video signal either automatically or by the action of the user.

10 4. Video interface according to any of claims 1, 2 or 3, characterized in that the sampling clock period and/or the control clock period of the digital display comprise n basic clock periods; that the active edge of the sampling pulse 15 is timed to coincide with a stable invariable moment of the analog video signal; and that the horizontal deflection period and horizontal synchronizing pulse of the digital video display are formed by a programmable number of basic clock periods; and that the vertical deflection period and the vertical synchronizing pulse are formed by a programmable number 20 of horizontal deflection periods.

25 5. Video interface according to claim 4, characterized in that the control means (35) compares the received horizontal synchronizing pulse with the generated horizontal synchronizing pulse at said basic clock frequency and synchronizes the horizontal synchronizing pulses by decreasing or increasing the number of the basic clock periods contained 30 in the generated horizontal synchronizing pulse instantaneously by one or more periods if the front edge of the generated horizontal synchronizing pulse occurs later or earlier, respectively, than the front edge of the received horizontal synchronizing 35 pulse.

6. Video interface according to claim 4 or 5, characterized in that the control means (35) comprises a counter means clocked by the basic clock and positively controlled by the received horizontal deflection signal for generating a horizontal synchronizing pulse.

7. Video interface according to any of claims 2 to 6, characterized in that the control means (35) compares the received horizontal synchronizing pulse with the generated horizontal synchronizing pulse at said basic clock frequency and synchronizes the horizontal synchronizing pulses by adjusting the basic clock frequency.

8. Video interface according to any of the preceding claims, characterized in that the received analog video signal is in an interlaced display mode, and that each generated horizontal deflection period contains two successive horizontal synchronizing pulses.

9. Video interface according to any of the preceding claims, characterized in that the received analog video signal complies with the character mode, and that every k th horizontal deflection period contains m additional horizontal synchronizing pulses for achieving an image stretching effect, where k and m are programmable parameters.

10. Video interface according to any of claims 4 to 9, characterized in that the resolution of the digital display (39) is N_1 pixels per horizontal line, and that the received analog video signal complies with a character mode in which there are N_2 pixels per horizontal line, where $N_1 < N_2$, and that the control means removes at least every 9th or every 17th and 18th pixel from each horizontal line by omitting the corresponding clock pulse

controlling the display.

11. Video interface according to any of the preceding claims, characterized in that the control means comprises a data transmission means 5 (33) for data transmission with a computer, e.g. for inputting the user's commands, preferably through a video input (31).

12. Video interface according to any of the preceding claims, characterized in that 10 the video interface comprises a user interface (32A) for giving the user's commands, and that the control means (32, 34, 35) performs a desired image adjustment on the screen in response to the user's commands.

15. Video interface according to any of the preceding claims, characterized in that the video interface comprises a user interface (32A) for inputting the user's commands, and that the control means (32, 34, 35) adjusts, in response to 20 the user's commands, the basic clock frequency generated by it to remove interferences occurring in the image displayed on the screen.

25. Video interface according to any of the preceding claims, characterized in that the control means comprises a memory (34) in which the information required to adjust the image is stored for different display modes.

30. Video interface according to any of the preceding claims, characterized in that the digitizing means (36) comprises an A/D converter for digitizing said at least one video signal, and that the control means (32) adjust the brightness and/or contrast level on the screen of the digital display by varying the voltage level of the lower 35 digitizing limit of at least one A/D converter and/or

the size of the voltage range to be digitized.

16. Video interface according to any of the preceding claims, characterized in that the digitizing means (36) has an associated conversion memory means (37) addressable by the digitized video output of the A/D converter and preferably programmable by the control means (32) for producing shaped digitized output data, and that the conversion memory means preferably performs a brightness, contrast, color and/or word length correction on the digitized video signal according to the properties of the digital video display to be controlled.

17. Video interface according to any of the preceding claims, characterized in that the digitizing means (36) has an associated means (110) addressable by the digitized video output of the A/D converter for increasing the number of displayed colours by the FRC or dithering technique.

18. Video interface according to any of the preceding claims, characterized in that the digital display (39) is a display divided into two simultaneously addressable blocks, and that an intermediate memory (121) for video data and means (120) for addressing the intermediate memory and the display are provided between the digitizing means (36) and the display (39) for supplying video data from the intermediate memory to the display.

19. Video interface according to any of the preceding claims, characterized in that the video interface comprises means (110) for chaining displays.

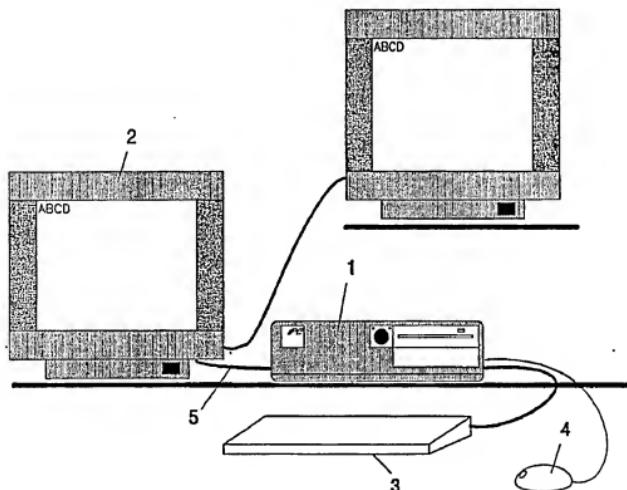


FIG.1

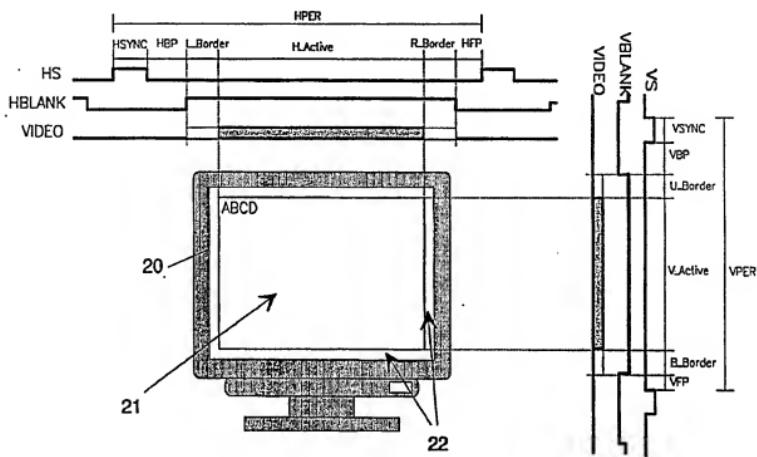


FIG. 2

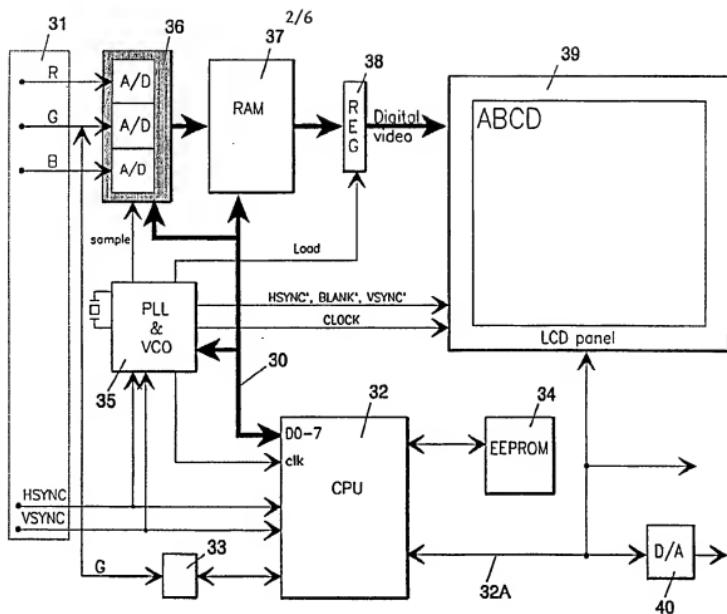


FIG. 3

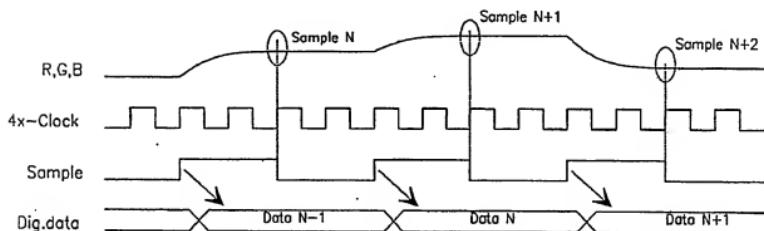
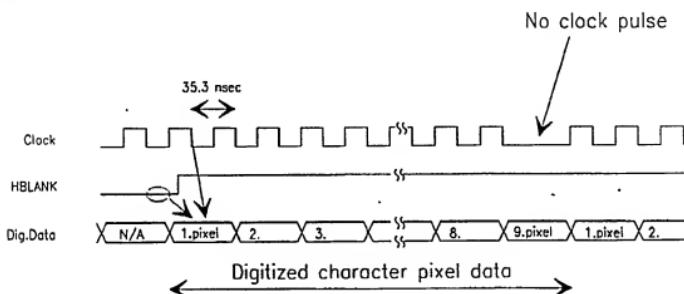
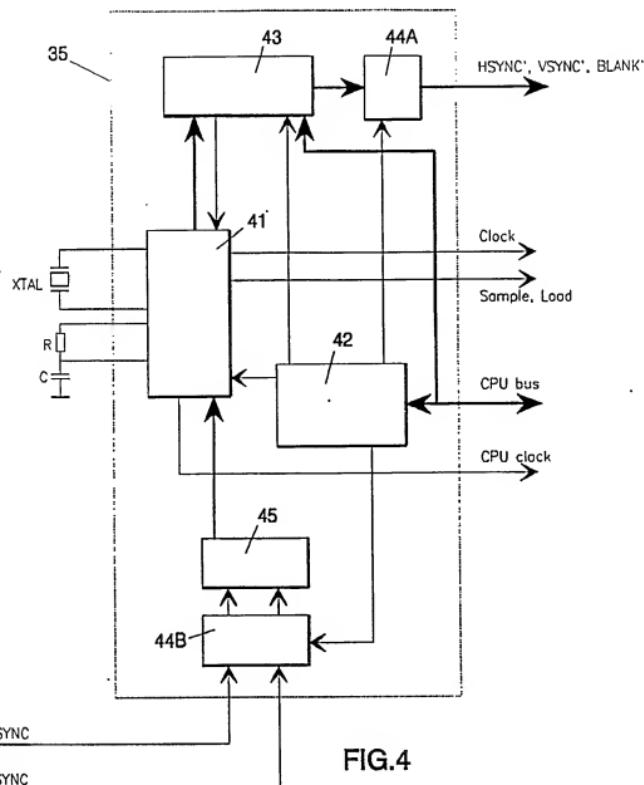


FIG. 5



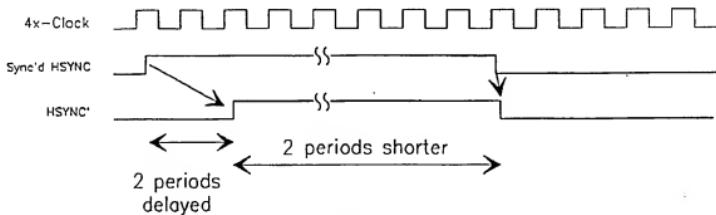


FIG. 6

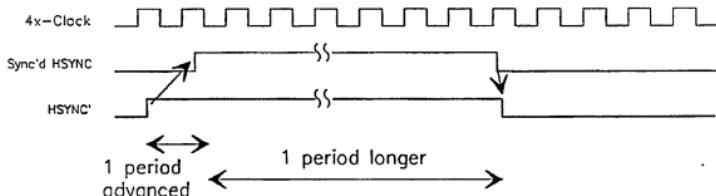


FIG. 7

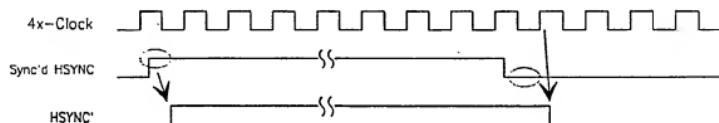


FIG. 8

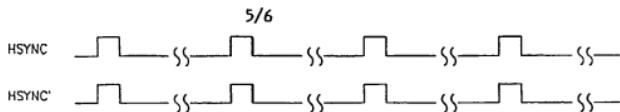


FIG. 10

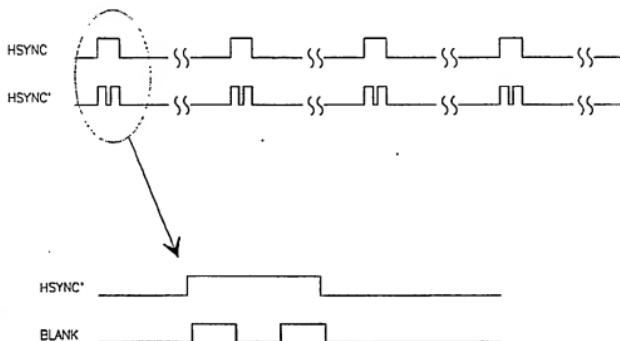


FIG. 11

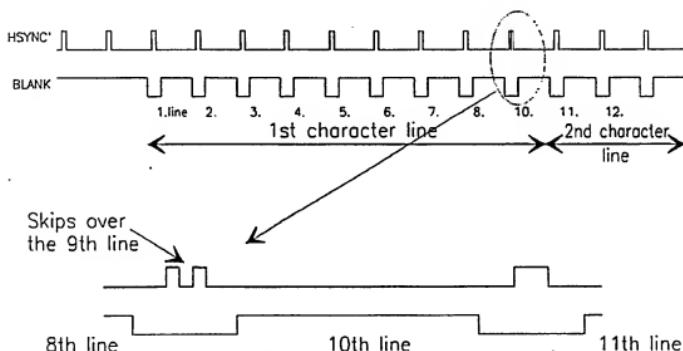


FIG. 12

6/6

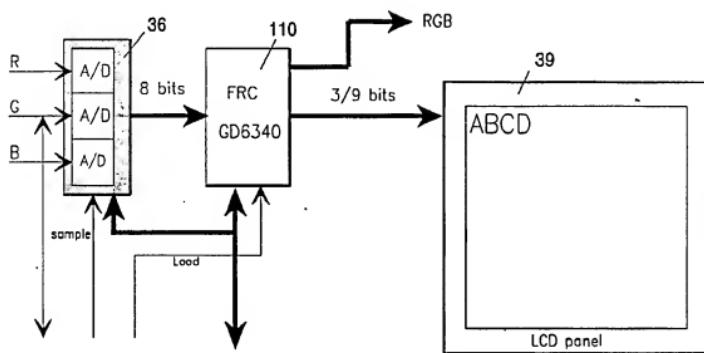


FIG. 13

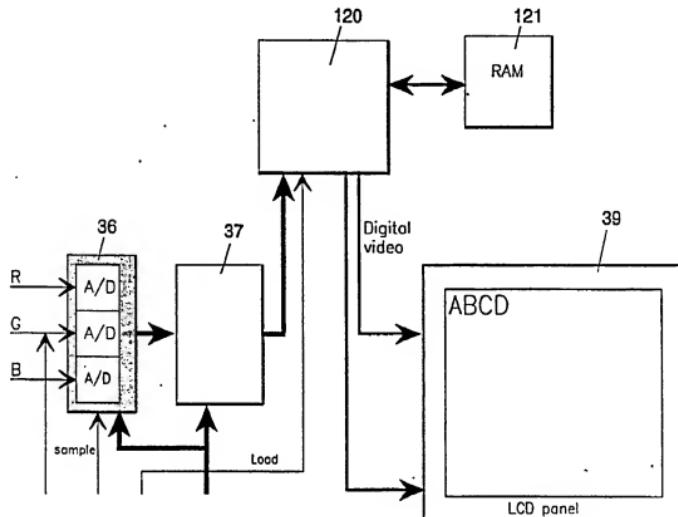


FIG. 14

A. CLASSIFICATION OF SUBJECT MATTER

IPC5: G09G 3/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC5: G09G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP, A2, 0269199 (MITSUBISHI DENKI KABUSHIKI KAISHA), 1 June 1988 (01.06.88) -----	1-19

Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:

- *A* document defining the general state of the art which is not considered to be of particular relevance
- *B* earlier document but published on or after the international filing date
- *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- *O* document referring to an oral disclosure, use, exhibition or other means
- *P* document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

X document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

Y document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

& document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 April 1993	04 -05- 1993
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Jan Silfverling Telephone No. +46 8 782 25 00

INTERNATIONAL SEARCH REPORT

Information on patent family members

26/02/93

International application No.

PCT/FI 93/00031

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A2- 0269199	01/06/88	JP-A-	63132288	04/06/88